

Development of the M2A1 Container Coatings ECP

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Introduction

- Container Coatings - use low cost Alkyd based technologies with significant rework and are high in volatile organic compounds (VOC's)
- Current Packaging interests – improved corrosion resistance, reduced environmental impact and reduced life cycle costs

Packaging Program Background



- Modular Artillery Container System (MACS) investigates the use of powder coatings for PA103A2 and PA161 applications around FY02
- Coating Goals (beyond current coating requirements)–

Improved Corrosion Resistance

Thin uniform Coating

Solventless formulation – no VOC's

Good chemical resistance

Program Summary



- Polyurethane Powder Coating available from industry meeting lusterless gloss definition (<10 per ASTM D523)
- ASTM B117 Corrosion Resistance over 336 hours possible with lusterless formulations
- Chemical Agent Decontamination Properties Acceptable on Specific Powder Formulations
- Spot Weld and Recesses in Container Designs presented Faraday Effects limiting areas of Coating Application
- E-coat Primer potential solution to Faraday Effect Issue at Increased Coating Costs
- Powder plus E-coat coating system for MACS containers was in excess of program budget
- MACS continued with alkyd coating system



FY06 Developments



- Future Concepts Division of ARDEC funded a “Reassessment” of Powder Coatings for Conventional Ammunition Containers Applications
- The Coating for Munitions Modernization Program receives Congressional Funding

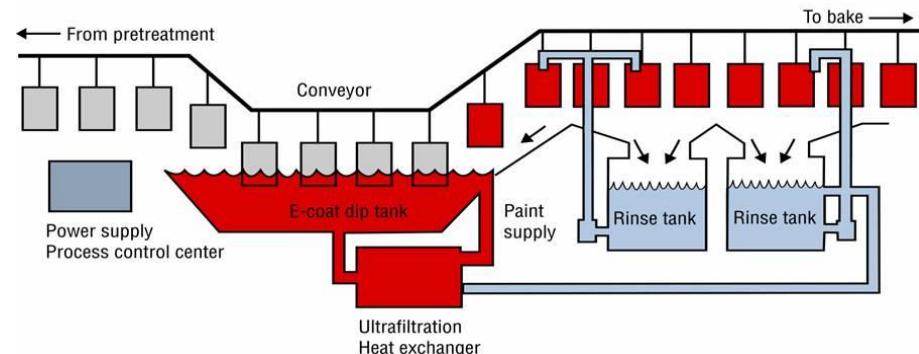
FY06 M2A1 Coating Process Assessment

- Alkyd Enamels Technology (Mil-E-52891, Mil-DTL-11195)
- Applied by spray or dip processes and adapted for container configurations
- Salt Spray resistance 150 hrs
- Poor Aesthetics
- Runs, Drips, Sags increase costs due to rework



FY06/07 Preliminary Research Results

- Powder formulations had improved since FY02.
- New Powder Coating Application Processes with improved “throw” into recesses exist.
- Cationic Acrylic E-coat Products could meet the established corrosion protection and UV durability requirements in the existing coating specification.
- Exterior lusterless gloss E-Coat applications did not exist for commercial market.



Coating Properties Data – Dec 07

	MIL-E-52891	Acrylic E-Coat	Urethane Powder	Results
APPLICATION	Low End One-Coat Dip Enamel	High End One-Coat Electrocoat	High End One-Coat Top Coat	
Cure (Double Acetone Rubs)	25-50	100+	TBD 100+ Expected	Significantly Exceed
60° Gloss	Maximum 8	< 5	< 6	Pass
VOC	High - Solvent Based (~5 lbs/gal)	Low - Water Based < 2.5 lbs/gal	No VOC's	Significantly Exceed
Adhesion	knife-tape 1/16"	Crosshatch 95-100%	ASTM D3359 4B min	Pass
Flexibility	1/4" Mandrel	1/4" Mandrel	1/4" Mandrel	Pass
Water Resistance	168 hours	168 hours	—	Pass
Salt Spray	5% Salt Fog 150 hours 1/8" scribe creep Trace rust / < 5 blisters	5% Salt Fog 700 hours 1/8" scribe creep No blistering or surface corrosion	5% Salt Fog 750 hours 1/8" scribe creep No blistering or surface corrosion	Significantly Exceed
Touch Up Adhesion	dip enamel 5 sec. No blisters/lift/ or bleeding	Will develop a touch-up product if necessary	Will develop a touch-up product if necessary	Development Need
Weather Resistance	168 hours WOM ΔL less than 4	168 hours WOM ΔL less than 4	168 hours WOM ΔL less than 4 expected	Pass
Dugway Testing	—	GD, HD, VX Decontamination	GD, HD, VX Decontamination	Pass



Program Results Jan 2008

- Single coat military Powder and E-coat is technically a viable option for exterior applications
- Acrylic e-coat meets current performance requirements for gloss, flexibility, water resistance
- Acrylic e-coat exceeds current performance requirements of alkyd coatings in salt spray resistance, and **weather resistance**
- Additional benefits include low VOC water based formula and Decontaminability

Hawaiian Exposure –Aug 07-Jun 08

Coconut Island, Oahu, Hawaii



Aug 07



Jan 08



Jun 08

E-Coat Reformulation Effort (Feb 08-Dec 09)



- Organic Color Additives degraded with UV exposure
- Container Weather Resistance requirement inadequate
- Baseline Container Weather Resistance determined
- Inorganic Color Additives used in revised formulation
- New Packaging Container Coating Requirements Established

FY09 Coating Properties Data

	MIL-E-52891	Acrylic E-Coat	Urethane Powder	Results
APPLICATION	Low End One-Coat Dip Enamel	High End One-Coat Electrocoat	High End One-Coat Top Coat	
Cure (Double Acetone Rubs)	25-50	100+	100+	Significantly Exceed
60° Gloss	Maximum 8	< 6	< 6	Pass
VOC	High - Solvent Based (~5 lbs/gal)	Low - Water Based < 2.5 lbs/gal	No VOC's	Significantly Exceed
Adhesion	knife-tape 1/16"	Crosshatch 95-100%	ASTM D3359, 4B min	Pass
Flexibility	1/4" Mandrel	1/4" Mandrel	1/4" Mandrel	Pass
Water Resistance	168 hours	168 hours	168 hours	Pass
Salt Spray	5% Salt Fog 150 hours 1/8" scribe creep Trace rust / < 5 blisters	5% Salt Fog 500 hours 1/8" scribe creep No blistering or surface corrosion	5% Salt Fog 700 hours 1/8" scribe creep No blistering or surface corrosion	Significantly Exceed
Touch Up Adhesion	dip enamel 5 sec. No blisters/lift/ or bleeding	Touch-up product identified	Touch-up product identified	Pass
Weather Resistance	168 hours WOM ΔL less than 4	700 hours WOM ΔL less than 4	700 hours WOM ΔL less than 4 expected	Significantly Exceed
Dugway Testing	—	GD, HD, VX Decontamination	GD, HD, VX Decontamination	Significantly Exceed

Outdoor Exposure of Existing M2A1 Powder Coating

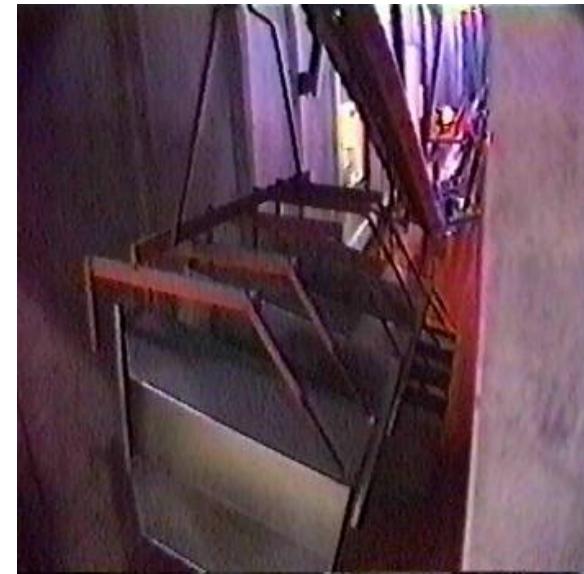


Apr 2009



Jul 09

Sep 09



Coating System Process Study for Container Applications

Purpose of the Study

To complete a finishing cost analysis for painting ammunition containers.

Compare equipment, layout and operating costs for

Electrocoat and powder finishing versus current systems.

Evaluate the impact of increasing line capacity.

Evaluate the impact of adding a second color.

Obtain an outside consultant to provide unbiased data and processing line cost estimates.



Coating System Study Assumptions

A mix of small and large, square and round containers.

Largest parts chosen were PA171 and PA154

Smallest parts chosen were M19A1 container and all lids

Pretreatment requirements and performance are equal.

Zinc phosphate with non chrome sealer

Paint cure requirements are equal.

375 degrees F metal temperature for 20 minutes

All interior surfaces must have paint coverage.

E-coat film build = 1.0 mils.

Powder film build = 2.5 mils.

One and two color system capability.

Annual production sizes:

2, 10, 20 & 30 million square feet per year.



Development of the M2A1 Container Coatings ECP



DRAWING SIZE A

NOTES:-

- 1 - REQUIREMENTS.
 - A - LEAD AND HEXAVALENT CHROMIUM FREE.
 - B - COLOR TAN NO. 33446 OR FOREST GREEN NO. 34079, IN ACCORDANCE WITH (IAW) FED-STD-595.
 - C - GLOSS AT 60 DEGREES SHALL BE LESS THAN 10 IAW ASTM D 523.
 - D - CURE TIME SHALL BE LESS THAN 30 MINUTES AND LESS THAN 400 DEGREES F (METAL TEMP).
 - E - THE COATING SHALL BE STRIPPABLE USING COMMERCIALLY AVAILABLE METHODS.

POWDER	E-16 MILS
CURED FILM THICKNESS	2.0 - 4.0 MILS
F-1.6 MILS	
PAINT FORMULATION	ALIPHATIC POLYURETHANE
G- ACRYLIC	
H- ELECTROSTATIC SPRAY	CATHODIC ELECTRODEPOSITION
- 2 - STEEL TEST PANELS SHALL BE PREPARED TO MEET THE FOLLOWING REQUIREMENTS. THE TEST PANELS SHALL BE CLEANED AND PRETREATED WITH ZINC PHOSPHATE IAW TT-C-481 PRIOR TO PAINTING.
 - A - ACCELERATED WEATHERING - TWO TEST PANELS SHALL BE EXPOSED FOR 700 HOURS IAW ASTM G155, CYCLE 1. THE CURED FILM SHALL SHOW NO CRACKING, COLOR CHANGE EXCEEDING A DELTA E OF +/- 4.0, BLISTERING, WRINKLING, OR LOSS OF ADHESION OF THE COATING NOR EVIDENCE OF SUBSTRATE CORROSION.
 - B - ADHESION - TWO TEST PANELS SHALL BE TESTED IAW ASTM D 3359, METHOD B. THE CURED FILM SHALL SHOW NO LIFTING, FLAKING, OR OTHER SIGNS OF LOSS OF ADHESION (MINIMUM OF 4B CLASSIFICATION OF ADHESION).
 - C - ENAMEL PAINT COMPATIBILITY - TWO TEST PANELS SHALL BE OVERCOATED WITH A BRUSH COAT OF ENAMEL IAW MIL-E-1195, DRAWING 12998366-2 OR DRAWING 9347108, AND ALLOWED TO AIR DRY. THE PANELS SHALL SHOW NO LIFTING, FLAKING, OR OTHER SIGNS OF LOSS OF ADHESION IAW ASTM D 3359, METHOD B.
 - D - FLEXIBILITY - THREE TEST PANELS SHALL BE BENT OVER A 1/4" MANDREL IAW ASTM D 522. THE CURED FILM SHALL SHOW NO SIGNS OF CRACKING OR LOSS OF ADHESION IN THE BEND AREA.
 - E - HARNESS - TWO TEST PANELS SHALL BE TESTED IAW ASTM D 3363. THE CURED FILM SHALL HAVE A MINIMUM SCRATCH PENCIL HARNESS OF 2H.
 - F - IMPACT RESISTANCE - TWO TEST PANELS SHALL BE TESTED FOR DIRECT AND INDIRECT IMPACT RESISTANCE IAW ASTM D 2794. THE CURED FILM SHALL WITHSTAND AN INDENTATION OF 30 INCH-POUNDS INTRUSION AND 10 INCH-POUNDS EXTRUSION WITHOUT CRACKING OR LOSS OF ADHESION.
 - G - SALT SPRAY RESISTANCE - TWO TEST PANELS SHALL BE EXPOSED FOR 400 HOURS IAW ASTM B 117. THE CURED FILM SHALL SHOW UNDERCUTTING OF NOT MORE THAN 1/8 INCH FROM THE LINE SCORED TO THE BASE METAL. THERE SHALL BE NO BLISTERING, WRINKLING, OR LOSS OF ADHESION OF THE COATING NOR ANY GENERAL SURFACE CORROSION OR PITTING.
- 3 - PAINTING FORMULATIONS AND COATING APPLICATIONS SHALL BE FREE OF OZONE DEPLETING SUBSTANCES (ODS)
- 4 - IDENTIFICATION OF THE "SUGGESTED SOURCE(S) OF SUPPLY" HEREON IS NOT TO BE CONSTRUED AS A GUARANTEE OF PRESENT OR CONTINUED AVAILABILITY AS A SOURCE OF SUPPLY FOR THE ITEM.

SUGGESTED SOURCE(S) OF SUPPLY FOR POWDER	
VENDOR	VENDOR PART NO.
VALSPAR CORPORATION 95 QUAKER OATS DRIVE JACKSON, TN 38301 (800) 659-8004	DESERT TAN 33446 FOREST GREEN 34079
SHERWIN WILLIAMS 4702 C POPLAR LEVEL RD LOUISVILLE, KY 40213 (502) 969-1887	100685 OR IF6059
PPG INDUSTRIES, INC. 10800 S. 13TH STREET OAK CREEK, WI 53154 (414) 764-6000	UHS2-20025 UHS2-90021
PROTECH POWDER COATINGS 939 MONOCACY RD YORK, PA 17404 (717) 767-6998	MLP20000 MLP40000
DUPONT COATING SLTNS 4130 LYMAN DR HILLARD, OH 43026 (800) 247-3866	US642H68 US642079
TIGER DRYLAC U.S.A., INC. 1261 EAST BELMONT ST ONTARIO, CA 91761 (800) 243-8148	UFT61950 UFG61850
	344/15010 344/50194

SUGGESTED SOURCE(S) OF SUPPLY FOR E-COAT		
VENDOR	VENDOR PART NO.	VENDOR PART NO.
PPG INDUSTRIES, INC. 10800 S. 13TH STREET OAK CREEK, WI 53154 (414) 764-6000	CR975(RESIN) CP983(PASTE)	CR975(RESIN) CR982(PASTE)

DISTRIBUTION STATEMENT A.
APPROVED FOR PUBLIC RELEASE.
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SPECIFICATION
CONTROL DRAWING
PART NO. 12998172

PMIC		CONTRACT NUMBER		DESIGN ACTIVITY	
REVISIONS				U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER PICATINNY ARSENAL, NEW JERSEY 07806-5000	
LTR	DESCRIPTION	DATE	APPD	CONTRACTOR	
- PRODUCT BASELINE ERR					
				DRAWN BY DPS	DATE(YR-MO-DA) 09-08-18
				CHECKER	ENGINEER D. SCALES
				DRAWING APPROVAL	
				DESIGN APPROVAL	
				UNIT WT.	SHEET
				COATINGS, HIGH PERFORMANCE (FOR AMMUNITION CONTAINERS)	
				SIZE CAGE CODE A 19200 12998172	

WARFIGHTER FOCUSED.

Requirements Drawing #12998172 Summary

Requirement	MIL-E-52891	Acrylic E-Coat	Urethane Powder	
Cured thickness	1.0-2.0 mils	1.0-1.5 mils	2.0-3.0 mils	
Impact Resistance ASTM D2794 30 in-lbs int, 10 in-lbs ext	—	Pass	Pass	
Specular Gloss ASTM D523 60° Gloss (<10)	Maximum 8	< 6	< 6	
Enamel Paint Compatibility ASTM D3359, Method B	Pass	Pass	Pass	
Adhesion ASTM D3359, Method B, 4B min	Pass	Pass	Pass	
Flexibility ASTM D522, ¼" Conical Mandrel	Pass	Pass	Pass	
Hardness ASTM D3363 (2H)	Pass	Pass	Pass	
Salt Spray ASTM B117	150 hours 1/8" scribe creep Trace rust / < 5 blisters	400 hours 1/8" scribe creep No blistering or surface corrosion	400 hours 1/8" scribe creep No blistering or surface corrosion	
Touch Up Adhesion	Touch-up product identified	Touch-up product identified	Touch-up product identified	
Accelerated Weathering ASTM G26, Method 1, Type BH	168 hours WOM ΔL less than 4	700 hours WOM ΔL less than 4	700 hours WOM ΔL less than 4 expected	
Dugway Testing (Not a Formal Requirement)	—	GD, HD, VX Decontamination	GD, HD, VX Decontamination	0.



JMC FY10 M2A1 Contract Solicitation

- Jan 09 Solicitation request asked for container price quotes based on alkyd coating, powder coating and e-coat systems for “Full and Open” and “Small Business Set-Aside” Contract .
- “Full and Open” Contract was awarded with selection of e-coat process based on unit cost in late July 2009.
- “Small Business Set-Aside” Contact was awarded with selection of powder coating process based on unit cost in August 2009 using an ECP powder.
- Polyurethane Powder will be implemented first since contractor had an existing powder coating process.
- E-Coat implementation will be delayed until coating line installation.



Acknowledgments

- Thanks for the assistance of the Acquisition, JMC, PM and ARDEC offices involved in this effort.
- Thanks for the cooperation of ARDEC manufacturing contractors involved in this program including Best Foam Fabricators, Conco Containers, Delfasco Containers and B-Way Containers.
- Special thanks for the effort and work accomplished on this program by the many individuals of PPG, Valspar, Sherwin Williams, Govesan Manufacturing, DuPont, TTX, Inc, and the University of Hawaii – Corrosion Research Center.



Development of the M2A1 Container Coatings ECP



TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.



Development of the M2A1 Container Coatings ECP



Information (Backup) Slides

Requirements Comparison

	MIL-P-53022B	MIL-P-53030A	MIL-DTL-53084		MIL-DTL-11195G	MIL-E-52891	MIL-DTL-64159	MIL-C-53039		URETHANE POWDER DRAWING 1298172	PPG THRESHOLD PROPERTIES
APPLICATION	Low end primer	Low end primer	High end primer (e-coat)		VOC Compliant 1coat	Low end 1 coat	CARC Topcoat	CARC Topcoat		Medium spec 1 coat for ammo boxes	Low end 1 coat
60° Gloss	min 10 / max 30	max 25	30-70		max 8	max 8	max 1.0	max 1.0		max 10	max 8
85° Gloss							3.5	3.5			max. 3.5# / gal.
VOC					3.5 #/gal.						
Adhesion	knife-tape 1/16"	knife-tape 1/16"	primer 5B / primer+tpct 4B ASTM D3359		knife-tape 1/8"	knife-tape 1/16"	4B over primer ASTM D3359	4B over primer ASTM D3359		4B ASTM D3359	knife-tape 1/16"
Knife test	Method 6304	Method 6304	Method 6304		Method 6304	Method 6304	Method 6304				Method 6304
Impact Resistance										50 inch-pounds (reverse & forward)	30 inch-pounds (to be confirmed)
Flexibility	Method 6221 (1/4" mandrel)	Method 6221, (1/4" mandrel)	ASTM D522 (1/4" mandrel) aluminum panel		ASTM 522 1/4" mandrel	Method 6221 (1/4" mandrel)	ASTM D522 (1/4" mandrel)	Method 6221 (1/4" mandrel)		ASTM D522 (1/4" mandrel)	Method 6221 (1/4" mandrel)
Water Resistance	ASTM D1308 168 hours 24 hr.recovery	ASTM D1308 168 hours 24 hr.recovery			18 hours 2 and 24 hour recovery	ASTM D1308 168 hours 24 hr. recovery	ASTM D1308 168 hours hr recovery 2H Δpencil little change gloss/color	ASTM D1308 168 hours 2 hr. recovery 2H Δpencil			168 hours 2 hr. recovery 2H Δpencil
Salt Spray	ASTM B117 unscored 336 hours trace rust/< 5 blis. Strip and eval.	ASTM B117 unscored 336 hours trace rust/< 5 blis. Strip and eval.	ASTM B117 'X' scribe 1000hours 1/8" scribe creep 3 B adhesion trace rust strip and eval.		ASTM D1654 TYPE I - 120 hr TYPE 2 - 240 hr min 7 rating	METHOD 6061 150 hours 1/8" scribe creep trace rust / < 5 blis. Strip and eval.				ASTM B117 240 hours 1/4" scribe creep no blistering or surface corrosion	ASTM B117 240 hours 1/4" scribe creep no blistering or surface corrosion
Hardness										2H	2H
Touch Up Adhesion	green 383,34094 urethane; knife blade test	green 383; knife test	see adhesion			dip enamel 5 sec. No blisters/lift/ or bleeding	self	self		Brushed on enamel adhesion test	Brushed on enamel adhesion test
Weather Resistance	Topcoated w/ 383; 18 mths Wash DC; trace rust	Topcoated w/ 383; 24 mths Wash DC; strip	Topcoated w/ 383/34094 (64159) ASTM G90 (560 mJ/m ² total) chalking (ASTM D4214); ΔE less than		24 mths Aberdeen MD, ASTM 610, rust rating 9	168 hours WOM (Method 6152) ΔL less than 4; also 18 months (scored) Wash DC	1000 hours ASTM G154, color change less than 2.5 NBS, no increase in gloss, chalking or adhesion loss	800 hours (ASTM G154) UV 340A; ΔE , 2.5		240 hours WOM (ASTM G26 method 1) ΔE less than 4	168 hours WOM (ASTM G26 method 1) ΔE less than 4
Hydrocarbon Fluid	ASTM D1308 TT S-735; 168 hour 2 hour recovery	ASTM D1308 TT S-735; 168 hour 2 hour recovery			70:30 isoctane/toluene 4 hrs immed/2 & 24 hr recovery		JP-8 168 hours 2 hours less than 2 H pencil; 24 hours no change hdns, adsn, app, no more than 0.5 gloss increase	ASTM D1308 TT S-735; 168 hour 2 hour recovery/24 hour recovery			70:30 isoctane/toluene 4 hrs immed/2 & 24 hr recovery
DS2	30 min 1/2 ml DS2; no softening or color change (ΔE <2.5)	30 min 1/2 ml DS2; little softening or color change					30 min 1 ml DS2; less than 2H softening, color change < 2.5 NBS units				
Acid Resistance							5 ml. 10% acetic / 1hour, no blister or color change				
Chemical and Live Agent							with primer, desorb max 40 micrograms GD, 180 micrograms HD				
IR reflectance							FED STD 141 method 6241				
Super Tropical Bleach (STB) resistance			1 ml. STB; 30 min less than 2 pencil hdns, max. color change 2.5 NBS				1 ml. STB; 30 min less than 2 pencil hdns, max. color change 2.5 NBS				
Cure time			ASTM D1153 30 strokes MIBK								ASTM D1153 30 strokes MIBK
Throw power			10 inches								10 inches

Dip Coating

- High cost (rework, transfer efficiency)
- Low performance (corrosion, aesthetics)
- High VOC / Need for incineration





The “True” Cost

~~Paint Price per Gallon~~

Process Efficiency
Square feet painted
Line speed (line of sight)
Ability to rack parts

Capital Investment
Justified by square footage

Material Usage

The amount of paint that is coated onto a part.

Labor

Manual handling
Re-work
Line operators
Loader/unloader
Painter
Supervisors

Applied Cost per Square Foot



Investigation Summary (Dec 08)

	MIL-E-52891	ACRYLIC E-COAT	Results
APPLICATION	Low End One-Coat Dip Enamel	High End One-Coat Electrocoat	_____
Cure (Double Acetone Rubs)	25-50	100+	Significantly Exceed
60° Gloss	Maximum 8	< 8	Pass
VOC	High - Solvent Based (~3.5 lbs/gal)	Low - Water Based < 2.5 lbs/gal	Significantly Exceed
Adhesion	knife-tape 1/16"	Crosshatch 95-100%	Pass
Flexibility	1/4" Mandrel	1/4" Mandrel	Pass
Water Resistance	168 hours	168 hours	Pass
Salt Spray	5% Salt Fog 150 hours 1/8" scribe creep Trace rust / < 5 blisters	5% Salt Fog 500 hours 1/8" scribe creep No blistering or surface corrosion	Significantly Exceed
Touch Up Adhesion	dip enamel 5 sec. No blisters/lift/or bleeding	Touch-up product identified	Pass
Weather Resistance	168 hours WOM ΔL less than 4	700 hours WOM ΔL less than 4	Significantly Exceed
Energetic Resistance	_____	Comp B-4, Black Powder, C-4, HMX, PBXN-9	Pass
Decontamination Testing	_____	GD, HD, VX Decontamination	Pass